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Declaration

I, Mariko Uchida, a translator of Fukuyama Sangyo Honyaku Center, Ltd., of 16-3, 2-chome, Nogami-cho, Fukuyama, Japan, do solemnly and sincerely declare that I understand well both the Japanese and English languages and that the attached document in English is a full and faithful translation, of the copy of Japanese Unexamined Patent No. Hei-5-323177 laid open on December 7, 1993.

Mariko Uchida

Mariko Uchida

Fukuyama Sangyo Honyaku Center, Ltd.

FOCUS ADJUSTMENT METHOD FOR VARIABLE-MAGNIFICATION OPTICAL SYSTEM

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Applicant: Asahi Optical Co. Ltd.

Inventor: Takayuki ITO

Inventor: Takuji HAMASAKI

Patent Attorney: Kunio MIURA

SPECIFICATION

[TITLE OF THE INVENTION]

Focus adjustment method for variable-magnification optical system

[ABSTRACT]

[Object] In terms of a focus adjustment method for a variable-magnification optical system which is, in order to make focus positions of a variable-magnification optical system with different focal lengths coincident, capable of adjusting, at two adjusting portions, positions in the optical

axis direction of lens groups to compose the variable-magnification optical system, the invention aims to obtain a method whereby a focus adjustment can more swiftly and simply be carried out.

[Construction] A variable-magnification optical system is provided as an optical system where, with a specific focal length, one of the two adjusting portions has a focus sensitivity and the other thereof has substantially no focus sensitivity, and focus of this variable-magnification optical system is adjusted by adjustment steps including: a step for focus adjustment, with this specific focal length, by one of the adjusting portions; and a step for focus adjustment, with a second focal length different from the above specific focal length, by the other of the adjusting portions.

[WHAT IS CLAIMED IS;]

[Claim 1] A focus adjustment method for a variable-magnification optical system which is, in order to make focus positions of a variable-magnification optical system with different focal lengths coincident, capable of adjusting, at two adjusting portions, positions in the optical axis direction of lens groups to compose said variable-magnification optical system, wherein

said variable-magnification optical system is provided as

an optical system where, with a specific focal length, one of said two adjusting portions has a focus sensitivity and the other thereof has substantially no focus sensitivity, and

focus of this variable-magnification optical system is adjusted by adjustment steps including: a step for focus adjustment, with said specific focal length, by one of said adjusting portions; and a step for focus adjustment, with a second focal length different from said specific focal length, by the other of said adjusting positions.

[Claim 2] The focus adjustment method for a variable-magnification optical system as set forth in Claim 1, wherein

said specific focal length and second focal length correspond to any one and the other of the wide end and tele end.

[Claim 3] The focus adjustment method for a variable-magnification optical system as set forth in Claim 1 or 2, wherein

$0.9<|m|<1.1$

is satisfied where a lateral magnification of the whole lens group of said other adjusting portion with said specific focal length is provided as m.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Field of the Invention] The present invention relates to a focus adjustment method for a variable-magnification optical system.

[0002]

[Prior Arts and Themes Thereof] In a variable-magnification optical system, it is indispensable to make focal positions coincide with at least two different focal lengths (or magnifications) and carry out a focus adjustment to determine a back focus. For this focus adjustment, it has been necessary to enable adjusting, at two adjusting portions, positions in the optical axis direction of lens groups to compose a variable-magnification optical system and carry out an adjustment at these two adjusting portions with two focal lengths, generally, with the wide end and tele end, respectively. Priorly, the two adjusting portions have been usually provided as a first group and the overall lens group or a first group and a master group (or a part thereof). However, as this focus adjustment, a set of adjustments at the wide end and tele end had to be repeatedly carried out a plurality of times through a trial and error process, therefore, operationality was inferior.

[0003]

[Object of the Invention] The present invention aims to obtain

a method whereby the above focus adjustment operations of a variable-magnification optical system can be easily carried out.

[0004]

[Outline of the Invention] The present invention has been made based on the knowledge that the reason that prior focus adjustment method is complicated is that the two adjusting portions have focus sensitivities with two focal lengths, respectively, namely, the focal position is changed when either is shifted. Therefore, the present invention is characterized in that, first, a variable-magnification optical system itself is provided as an optical system where, with a specific focal length, one of two adjusting portions has a focus sensitivity and the other thereof has substantially no focus sensitivity, and focus of this variable-magnification optical system is adjusted by adjustment steps including: a step for focus adjustment, with the specific focal length, by one of the adjusting portions; and a step for focus adjustment, with a second focal length different from the above specific focal length, by the other of the adjusting portions.

[0005] According to this focus adjustment method, most simply, by only, after carrying out a focus adjustment, with a specific focal length, by one of the two adjusting portions, namely,

by an adjusting portion having a focus sensitivity, carrying out a focus adjustment, with another focal length, by the other adjusting portion, the focus adjustment can be completed. The two focal lengths for a focus adjustment are preferably the wide end and tele end. In addition, having substantially no focus sensitivity can be defined, in detail, as satisfying $0.9<|m|<1.1$ where a lateral magnification of the whole lens group of the adjusting portion is provided as m, for example.

[0006] Here, the "focal length" is strictly a concept for designing a variable-magnification optical system by infinite standards, and for designing a variable-magnification optical system by limited standards, strictly, a "magnification" concept is employed. However, the "focal length" of the present invention includes the "magnification" concept for a limited standard design. In addition, the "focus adjustment" referred to in the present specification means, as is clear from the above description, a focus adjustment when a variable-magnification optical system is manufactured and assembled, and does not mean focusing of a normal taking lens.

[0007]

[Preferred Embodiments of the Invention] Hereinafter, the present invention will be described based on embodiments. Fig. 1 is a view for generally describing a focus adjustment method

of a variable-magnification optical system and a focus sensitivity thereof. Although this variable magnification optical system is composed of four groups of a first group through a fourth group, herein, consideration will be given to the same in a manner divided into a front group A and a rear group B, which are respectively shifted during a focus adjustment, and a third lens group C. Namely, the front group A and rear group B have a concept of lens groups to be shifted for a focus adjustment, and the rear group B means the whole lens group behind the front group A shifted during the focus adjustment. The third lens group C is, if it exists, a lens group positioned behind this rear group B and a lens group uninvolved in the focus adjustment. Herein, the present invention also holds true even when another lens group exists in front of the front group A or between the front group A and rear group B.

[0008] In this variable-magnification optical system, a shifting amount in the optical axis direction of the front group A for a focus adjustment is provided as ΔX_A, a shifting amount in the optical axis direction of the rear group B is provided as ΔX_B, and shifting amounts of a focus plane as a result of a shift of the adjusting lens group A and rear group B are provided as ΔP_S and ΔP_L.

[0009] Focus sensitivities of the front group A and rear group B at a wide end (short focal distance) of this variable-magnification optical system can be expressed as follows.

$\Delta P_S \,/\, \Delta X_A = (1-m_{SA}{}^2) m_{SR}{}^2$

$\Delta P_S \,/\, \Delta X_B = (1-m_{SB}{}^2) m_{SC}{}^2$

Similarly, focus sensitivities of the front group A and rear group B at a tele end (long focal distance) can be expressed as follows.

$\Delta P_L \,/\, \Delta X_A = (1-m_{LA}{}^2) m_{LR}{}^2$

$\Delta P_L \,/\, \Delta X_B = (1-m_{LB}{}^2) m_{LC}{}^2$

[0010] The above is provided wherein m_{SA} shows a lateral magnification of the front group A with a short focal length, m_{SR} shows a lateral magnification of all lens groups behind the front group A with a short focal length, m_{SB} shows a lateral magnification of the rear group B with a short focal length, m_{SC} shows a lateral magnification of the third lens group C with a short focal length, m_{LA} shows a lateral magnification of the front group A with a long focal length, m_{LR} shows a lateral magnification of all lens groups behind the front group A with a long focal length, m_{LB} shows a lateral magnification of the rear group B with a long focal length, and m_{LC} shows a lateral magnification of the third lens group C with a long focal length. Here, if no third lens group C exists, m_{SC} and $m_{LC} = 1$.

[0011] These expressions show that the focus sensitivity of the front group A or rear group B with a short focal length or a long focal length becomes zero when the absolute value of m_{SA}, m_{SB}, m_{LA}, or m_{LB} is made 1 or m_{SR}, m_{SC}, m_{LR}, or m_{LC} is made zero. It is sufficiently possible to design such a variable-magnification optical system.

[0012] And, the present invention is characterized in that, after designing a variable-magnification optical system as such, as a first step, with one of the long and short focal lengths (for example, the wide end) where the focus sensitivity of one adjusting lens group (for example, the rear group B) becomes approximately zero, a focus adjustment is carried out by the adjusting lens group (for example, the front group A) whose focus sensitivity is not zero, and as a second step, with the other of the long and short focal lengths (the tele end), a focus adjustment is carried out by the adjusting lens group (the rear group B) whose focus sensitivity was zero with the above-described one focal length (wide end).

[0013] Next, the present invention will be described in terms of further detailed variable-magnification lens groups.

<Embodiment 1> As shown in Fig. 2,

Focal length f; 100(S)~300(L)mm,

Lens composition; three groups (the 1st group is a focusing group,

the 2^{nd} and 3^{rd} groups are variable-magnification groups, and the 1^{st} group is not shifted during variable power),

Focus adjusting lens groups; the 1^{st} group and whole rear group (2^{nd} and 3^{rd} groups).

[0014] In this variable-magnification optical system, where the lateral magnification m of the rear group when f = 100mm is provided as 1.0, and m when f = 300mm is provided as 3.0, focus sensitivities are,

when f = 100mm,

ΔP_S / ΔX_A = m^2 = 1.0

ΔP_S / ΔX_B = $1-m^2$ = 0 (no focus shift)

when f = 300mm

ΔP_L / ΔX_A = m^2 = 9.0

ΔP_L / ΔX_B = $1-m^2$ = -8.0

[0015] Accordingly, when f =100mm, the front group A, that is, the first group is shifted for a focus adjustment, and next, with f = 300mm, the rear group B, that is, the whole of the second and third groups are shifted for a focus adjustment, whereby the focus adjustment is completed.

[0016]

<Embodiment 2> As shown in Fig. 3,

Focal length f; 50(S)~100(L)mm,

Lens composition; two groups (the 1^{st} group is a focusing group,

the 1^{st} and 2^{nd} groups are variable-magnification groups),

Focus adjusting lens groups; the 1^{st} group and 2^{nd} group.

[0017] In this variable-magnification optical system, where the lateral magnification m of the rear group when f = 50mm is provided as -0.5, and m when f = 100mm is provided as -1.0, focus sensitivities are,

when f = 50mm,

ΔP_S / ΔX_A = m^2 = 0.25

ΔP_S / ΔX_B = $1-m^2$ = 0.75

when f = 100mm

ΔP_L / ΔX_A = m^2 = 1.0

ΔP_L / ΔX_B = $1-m^2$ = 0 (no focus shift)

[0018] Accordingly, when f =100mm, the front group A, that is, the first group is shifted for a focus adjustment, and next, with f = 50mm, the rear group B, that is, the second group is shifted for a focus adjustment, whereby the focus adjustment is completed.

[0019]

<Embodiment 3> As shown in Fig. 4,

Focal length f; 50(S)~100(L)mm,

Lens composition; two groups (the 1^{st} group is a focusing group, the 1^{st} and 2^{nd} groups are variable-magnification groups),

Focus adjusting lens groups; the 1^{st} group and 2^{nd} group.

[0020] In this variable-magnification optical system, where the lateral magnification m of the rear group when f = 50mm is provided as -2.0, and m when f = 100mm is provided as -2.0, focus sensitivities are,

when f = 50mm,

ΔP_S / ΔX_A = m^2 = 1.0

ΔP_S / ΔX_B = $1-m^2$ = 0 (no focus shift)

when f = 100mm

ΔP_L / ΔX_A = m^2 = 4.0

ΔP_L / ΔX_B = $1-m^2$ = -3.0

[0021] Accordingly, when f =50mm, the front group A, that is, the first group is shifted for a focus adjustment, and next, with f = 50mm, the rear group B, that is, the second group is shifted for a focus adjustment, whereby the focus adjustment is completed.

[0022] Next, with reference to Fig. 5 and Fig. 6, an embodiment where the present invention has been applied to an actual lens barrel will be described. This embodiment is an embodied focus adjustment mechanism of the three-group lens system (Embodiment 1) of Fig. 2. The lens system is composed of three groups of a first lens group 11, a second lens group 12, and a third lens group 13. The first lens group 11 corresponds to the front group A, and the second lens group 12 and third

lens group 13 correspond to the rear group B. The first lens group 11, second lens group 12, and third lens group 13 are supported by a first-group lens frame 14, a second-group lens frame 15, and a third-group lens frame 16, respectively, and the second group frame 15 and third-group lens frame 16 are fixed to the second-group shifting frame 17 and a third-group shifting frame 18, respectively.

[0023] At a mount ring 20 to be attached and detached with respect to a camera body, a fixing ring 21 is fixed, and at the front end of this fixing ring 21, a helicoid ring 23 is fixed by a setscrew 22. With an outer circumferential helicoid 23H of this fixing helicoid ring 23, an inner circumferential helicoid 24H of a focus helicoid ring 24 is screwed, and with a minute screw 24f formed on the inner circumference of a front-end portion of this focus helicoid ring 24, a precision screw 14f on the outer circumference of the first-group lens frame 14 is screwed. This screwed relationship between the precision screws 24f and 14f construct a focus adjustment portion (ΔX_A) of the front group A. Here, although the first-group lens frame 14 (first lens group 11) is shifted in the optical axis direction by turning the focus helicoid ring 24, this is a focusing in a condition where assembly has been completed.

[0024] To the fixing ring 21, an outer tube 26 is fixed while being positioned on the forward, outer surface of the same, and between this outer tube 26 and a rear portion of the fixing ring 21, a zooming ring 27 is freely turnably supported. In addition, in an inner circumferential portion of the fixing ring 21, a cam ring 28 is freely turnably supported, and the cam ring 28 and zooming ring 27 are coupled by radial turn interlocking projections 29 and 30 so as to perform an equal turn at all times. In the cam ring 28, cam grooves 32 and 33 for the second lens group 12 and third lens group 13 are formed, and in these cam grooves 32 and 33, cam pins 34 and 35 fixed to the second-group shifting frame 17 and third-group shifting frame 18 are fitted, respectively. The cam pins 34 and 35 are further fitted into linear guide grooves 36 and 37 (Fig. 6) formed in the fixing ring 21 and thereby enables only a linear shift in the optical axis direction of the second lens groups 12 and third lens group 13. The cam grooves 32 and 33 are formed so as to, when the cam ring 28 is turned, provide the second lens group 12 and third lens group 13 with variable-power, predetermined shifting tracks in the optical axis direction.
[0025] Between the fixing ring 21 and cam ring 28, a focus adjustment mechanism to shift the second lens group 12 and third lens group 13 (rear group B) in the optical axis direction as

one body is provided. On the fixing ring 21, a pair of focus adjustment rods 40 and 41 are supported at radially opposed positions so as to be slidable in a direction parallel to the optical axis. These focus adjustment rods 40 and 41 each have an L-shaped bent portion 42 at the front end thereof, and the front end of this L-shaped bent portion 42 is fitted in a circumferential groove 43 formed in the cam ring 28. The L-shaped bent portion 42 and circumferential groove 43 are free to relatively turn therebetween. The cam ring 28 is supported on the fixing ring 21 while enabling a shift in a direction parallel to the optical axis, and accordingly, when the focus adjustment rods 40 and 41 are shifted in the direction parallel to the optical axis, as a result, the cam ring 28, that is, the second lens group 12 and third lens group 13 latched with the cam ring 28 by the cam grooves 32 and 33 are shifted in the optical axis direction as one body. By this integrated shift of the second lens group 12 and third lens group 13 as a result of a shift of the cam ring 28, a focus adjustment (ΔX_B) of the rear group B is carried out.

[0026] In these focus adjustment rods 40 and 41, respectively, a pair of long holes 44 in a direction parallel to the optical axis are formed, and in this long hole 44, guide-cum-setscrew 45 to be screwed with the fixing ring 21 is inserted.

Furthermore, in the focus adjustment rod 40, an eccentric pin inserting hole 46 is formed, while in the fixing ring 21, an eccentric adjusting jig inserting hole 47 having its center at a position eccentric from this eccentric pin inserting portion 46 is formed. The eccentric adjusting jig 50 has a cylindrical portion 51 to be fitted into the eccentric pin inserting hole 46 and an eccentric pin 52 which exists at a position eccentric from this cylindrical portion 51 and to be fitted into the eccentric adjusting jig inserting hole 47.

[0027] The present lens barrel with the above-described construction can carry out, by the following steps, the same focus adjustment as that described in terms of Fig. 2. It is anticipated that the variable-magnification lens system composed of the first through third lens groups 11, 12, 13 has been designed so that, with the shortest focal length, the focus sensitivity of the rear group B becomes zero.

[0028] (1) By turning the zooming ring 27, the focal length by the second lens group 12 and third lens group 13 is made into a minimum-length state (S end), and by turning the focus helicoid ring 24, an infinity photographic condition is provided (if by infinite standards).

[0029] (2) By turning the first-group lens frame 14, the position in the optical axis direction of the first lens group

11 is adjusted to make the first lens group 11 focus on a predetermined position. This adjustment corresponds to the ΔX_A adjustment in the embodiment of Fig. 2, and is also called a back focus (f_B) adjustment. After finishing this adjustment, a first-lens-frame clamping ring 25 is tightened to fix the first-group lens frame 14 to the focus helicoid ring 24.

[0030] (3) By turning the zooming ring 27, the focal length by the second lens group 12 and third lens group 13 is made into a maximum-length state (L end).

[0031] (4) In a condition where the guide-cum-setscrew 45 has been loosened, the eccentric pin 52 of the eccentric adjusting jig 50 is fitted in the eccentric adjusting jig inserting hole 47, and the cylindrical portion 51 is fitted in the eccentric pin inserting hole 46. In this condition, if the eccentric adjusting jig 50 is turned around the eccentric pin 52, owing to the eccentric relationship between the eccentric pin 52 and cylindrical portion 51, the pin adjustment rod 40 is shifted in a direction parallel to the optical axis, and owing to the latching relationship between the L-shaped bent portion 42 and circumferential groove 43, the cam ring 28 and second lens group 12 and third lens group 13 (rear group B) are shifted as one body, therefore, by this adjustment, the focus position is made to coincide with a position of the first adjustment. This

adjustment corresponds to the adjustment of ΔX_B in the embodiment of Fig. 2, and is also called a zooming adjustment. After this adjustment, the guide-cum-setscrew 45 is tightened to fix positions in the optical axis direction of the point adjusting rods 40 and 41 and cam ring 28.

[0032] As in the above, according to the present invention, it is impossible to complete a focus adjustment with only a one-time adjusting step each at the short focus side and long focus side (a set of long and short adjustments). However, in a case where the focus sensitivity of either adjusting portion with a specific focal length is not zero in a strict sense or where an error in the initial state is great, the present invention does not prohibit further carrying out of a plurality of sets of focus adjustments.

[0033]

[Effects of the Invention] As in the above, according to the present invention, in a variable-magnification optical system having two focus adjusting portions, most simply, by only, after carrying out a focus adjustment, with a specific focal length, by one of the two adjusting portions, namely, an adjusting portion having a focus sensitivity, carrying out a focus adjustment, with another focal length, by the other adjusting portion, the focus adjustment can be completed,

therefore, compared to the conventional focus adjustment through a trial and error process, operating efficiency is greatly improved.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Fig. 1] A lens construction diagram showing a general example of a variable-magnification optical system for explaining a focus adjustment method of the present invention.

[Fig. 2] A lens construction diagram showing a first embodiment of a focus adjustment method of the present invention.

[Fig. 3] A lens construction diagram showing a second embodiment of a focus adjustment method of the present invention.

[Fig. 4] A lens construction diagram showing a third embodiment of a focus adjustment method of the present invention.

[Fig. 5] An upper half sectional view showing an example of a mirror barrel provided with the lens construction and detailed adjusting mechanism of the above-described Embodiment 1 (Fig. 2) of the present invention.

[Fig. 6] A development in the vicinity of a cam ring of the lens barrel of Fig. 5.

[Description of Symbols]

A B Focus adjustment lens group (adjusting portion)

Fig.1

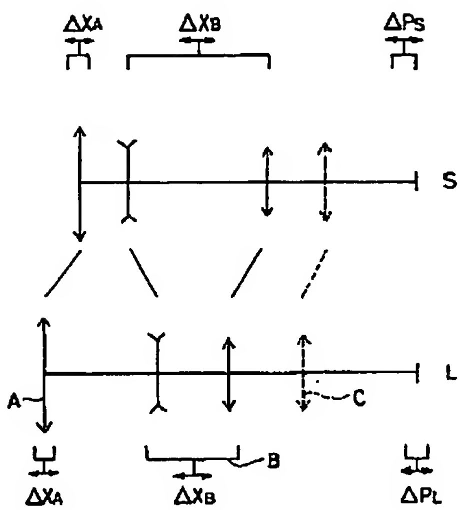

Fig.2

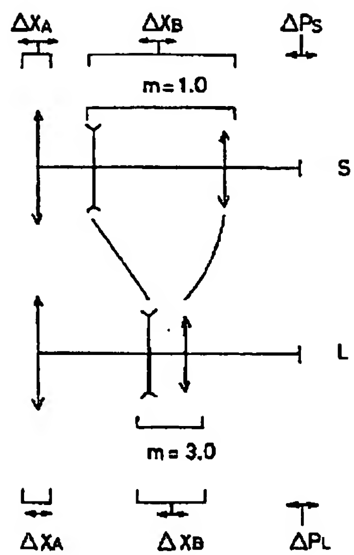

Fig.4

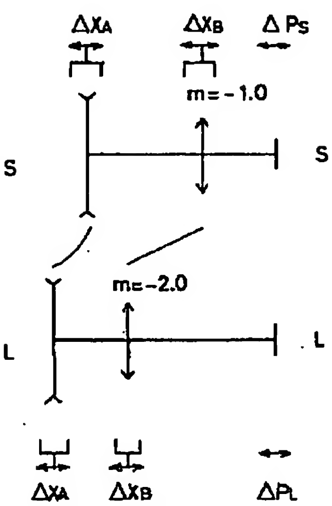

Fig.3

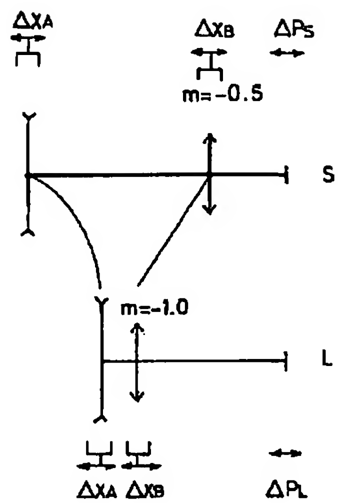

Fig.6

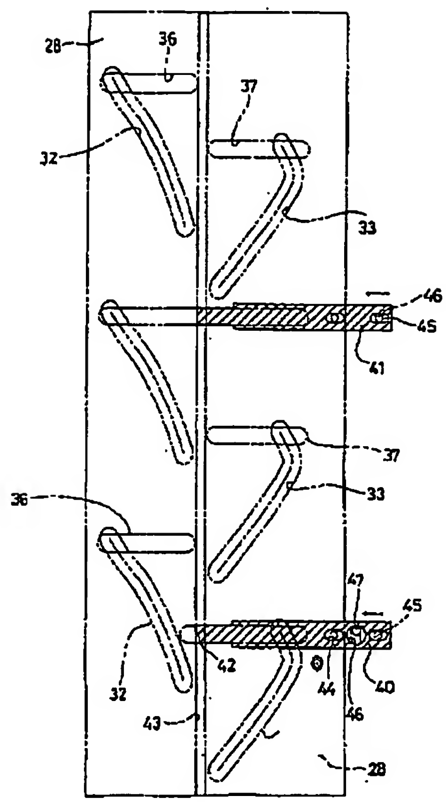

Fig.5